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COMPLETE SPECIFICATION

Improved means for Analysing Gaseous Substances

I, JOHN HUGH DAVEY WALTON, a British Subject, of Bamford House, Tetbury, in the County of Gloucestershire, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an improved means for analysing gaseous substances.

It is often desirable to provide means for rapidly detecting changes in the composition of a mixture of gases, i.e. detecting quantitatively an admixture or abstraction of a constituent.

An example is the use of such means in mines where it is important to detect explosive impurities, such as methane, in the atmosphere and to signal the presence of such impurities without delay.

In the present invention use is made of the fact that changes in the composition of a gas produce changes in its sound propagation characteristics, i.e. changes in the velocity and/or the attenuation of sound passing through the gas.

Consideration will now be given to sound velocity in a gas. It is known that sound velocity in a gas is a function of the absolute temperature and of a quantity, which depends only on the nature of the gas. This quantity, which is specific to any particular gas, is hereinafter referred to as the velocity index.

In the case of a pure gas, it may be shown that $C=T^{\frac{1}{2}}(R\gamma/M)^{\frac{1}{2}}$ where C is the velocity of sound, T is the absolute temperature, R is a gas constant, γ is the ratio of the specific heats and M is the molecular weight. Therefore the velocity index of a gas is defined as $C/T^{\frac{1}{2}}$ which for a pure gas is equal to $(R\gamma/M)^{\frac{1}{2}}$. A mixture of gases has a velocity index which is an average of the indices of its constituents.

It is therefore possible to determine the quantity of a gas being added to or abstracted from another gas, because a change in composition changes the velocity index of that composition, and it is correspondingly a more particular object of the present invention to provide means for measuring changes in the velocity index of a gas as a fraction of the velocity index before change and thereby indicate instantaneously the quantity of a known constituent which is being added or abstracted.

Generally, only one constituent at a time can be dealt with in this way; but in some cases the quantities of two constituents can be determined during addition or abstraction for the following reason. Some gases introduce considerable sound attenuation whilst in others it is negligible. In some cases it is therefore possible to measure the respective quantities of two known gases added to a known third gas, if the two gases have pronounced and negligible sound attenuation properties, respectively, and provided that separate measurement is taken of the combined effect of the two gases on sound velocity on the one hand, and the effect of one of them on sound attenuation, on the other hand.

The proposed means are applicable to cases where, for analysis or detection, it is sufficient to know that there has been a change in velocity index and/or in attenuation, either because only one or two specific constituents or impurities are likely to be present, as, for example, in the air adjacent a known volatile liquid; or where the presence of any impurity calls for action, as, for example, in the air inside a submarine.

According to the present invention I provide an instrument for determining the nature of a gas comprising a self-excited oscillator supplying electrical energy to one or more sending transducers adapted to transmit sound energy through a vessel containing a variant gas, one or more receiving transducers adapted to receive the said sound energy, and means for comparing the electrical signals obtained as regards phase and amplitude with those obtained by transmission of sound energy

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through a datum gas in a vessel.

The means for measuring the said characteristics may comprise a volt meter or phase meter.

Velocity changes appear as changes in the phase relationship between the sending and receiving transducers and are registered by the phase meter.

Attenuation corresponds to an amplitude drop and therefore appears as a voltage disconformity between the sending and receiving transducers and is registered by the volt meter.

The length of the tube constitutes the transmitting distance of the transducers, i.e. the path length of the sound being transmitted.

It will be seen that simultaneous measurement may be made of the gas whose composition has to be determined (referred to as the variant gas) and another gas whose composition is known (hereinafter referred to as the datum gas) and wherein changes in the variant gas are expressed as a fraction of the properties of the datum gas.

A phase meter and a volt meter may be used to measure the phase and amplitude relationship of the receiving transducers. Both meters may be calibrated to read zero under conditions of conformity (i.e. when the variant and datum gases are the same) and to show any disconformity in terms of a percentage change in one or two of the constituents of the variant gas.

The transmitting distances of the transducers are of an order giving a phase change accumulation or an attenuation of recordable magnitude. Where a variant and a datum transducer set are employed, the two transmitting distances are normally identical but they may be adjusted to differ by a fraction of a wavelength to ensure a zero reading at a predetermined difference between the datum and the variant gases.

To make the instrument of readily portable size, the transmitting distances are kept short by employing ultrasonic frequencies, the transducers being correspondingly adapted for ultrasonic transmission.

The said means for measuring the characteristics of the output transducers may, in all embodiments of this invention comprise a relay-operated signalling means.

Several forms of the instrument are illustrated in the accompanying drawings wherein:—

Fig. 1 is a diagram of a first form of the instrument,

Fig. 2 is a diagram of a second form of instrument,

Fig. 3 is a front elevation of an instrument based on the form shown in Fig. 2,

Fig. 4 is a rear elevation of the instrument partly in section,

Fig. 5 is a side elevation of the instrument, partly in section,

Fig. 6 is a section on line VI—VI in Fig. 3,

Fig. 7 is an enlarged detail of Fig. 6,

Fig. 8 is an enlarged section on line VIII—VIII in Fig. 6,

Fig. 9 is a wiring diagram, and

Figs. 10—12 are diagrams of modified arrangements according to the invention.

Referring to Fig. 1 of the drawings, the instrument comprises an oscillator 10, a sending transducer 11, a receiving transducer 12, the transducers being secured to the ends of a perforated tube 13 which contains the sound path between the two transducers. The input leads of the transducer 11 and the output leads of the transducer 12 are taken to a phase meter 14 and a volt meter 15 as shown.

In use the tube 13 is exposed to the gas to be determined. Changes in the composition of the gas affect the velocity index of the mixture and are indicated by the phase meter. An admixture or subtraction of a gas which produces a change in attenuation is indicated by the volt meter.

The theoretical basis of the instrument will now be described with the following conventions:—

C = velocity of sound in the tube,
w = $2\pi \times$ frequency transmitted,
x = length of tube,
Φ = phase difference between sending and receiving transducers,
Φ_t = phase shift introduced by the transducers themselves,
Φ_m = phase shift as measured by the instrument,
T = absolute temperature,
t = time taken by the sound wave to travel distance x,
U = velocity index of gas in tube,
S = sensitivity of instrument to small fractional changes of U,

It will be seen that:—

$$t = x/C \qquad (1)$$

and

$$\Phi = w\,t = w\,x/C \qquad (2)$$

Since

$U = C/T^{\frac{1}{2}}$ by definition,

$$\Phi = w\,x/T^{\frac{1}{2}}\,U \qquad (3)$$

Further

$$\Phi_m = \Phi_t + \Phi = \Phi_t + w\,x/T^{\frac{1}{2}}\,U \qquad (4)$$

or

$$U = w\,x/T^{\frac{1}{2}}\,(\Phi_m - \Phi_t) \qquad (5)$$

Equation (5) shows that having a knowledge of the path length, the frequency, the absolute

temperature and the phase shift in the transducers, the velocity index is calculable from the phase measurement Φ_m, i.e. the phase meter can be calibrated to show a change in the proportion of two known gases. Since Φ is periodic the range of the instrument should of course be confined to a phase difference of less than 360° to avoid ambiguities.

By differentiation of equation (4)

$$S = -U\, d\Phi/dU = w\, x/T^2\, U \qquad (6)$$

Since w and x are under the control of the designer, a good sensitivity of the instrument may be realised by making the expression $w\,x$ a maximum.

Also, since the sensitivity is proportional to the tube length and the frequency but inversely proportional to the range over which a reading free from periodic repetition may be taken, the instrument may be designed for a sensitive reading of small composition changes or a less sensitive reading of larger composition changes as the case may be.

Fig. 2 illustrates a form of the instrument wherein the likelihood of error due to temperature change or unreliable aspects of the electrical equipment is reduced to a minimum.

Referring to Fig. 2 an oscillator 10 is wired to energise a first set of transducers 11, 12, whose sound path is in a perforate tube 13 accessible to the variant gas and a second set of transducers 16, 17, whose sound path is in a sealed tube 18 containing a datum gas. The output leads of the receiving transducers 12 and 17 are wired to a phase meter 14 and a volt meter 15 as shown.

The theoretical basis of this form of instrument is as follows. If the transducers, the path lengths and the velocity indices are identical, the phase meter reads zero. If the velocity index of the variant gas changes from U to $U+\delta U$ where $\delta U \ll U$, then by applying equation (6) the phase difference Φ between the two receiving transducers is given by

$$\Phi \simeq S\, \delta U/U \qquad (10)$$

In other words, if U is known δU can be calculated and the phase meter calibrated accordingly.

This arrangement (Fig. 2) has the following advantages: The effect of temperature changes on the phase shift occurs as a fraction of δU rather than as a fraction of U. The effect of temperature is therefore negligible over small ranges.

The instrument is direct reading and it is relatively immune from drift in calibration because errors due to a difference in the temperature of the two tubes are eliminable by juxtaposing the tubes and small changes in the frequency do not affect the reading since such changes would affect both paths equally.

In this example the instrument is adapted for installation in a mine to detect the presence of methane and/or carbon dioxide in the air. The datum tube 18 is therefore filled with a sample of clean air, whilst the interior of the variant tube 13 is exposed to the ambient air in the mine.

It is known that methane is lighter than air and it therefore tranmits sound at a relatively greater velocity but it does not introduce appreciable sound attenuation. Carbon dioxide is heavier than air with a corresponding depression of sound velocity, but it does introduce sound attenuation.

Therefore an incidence of methane is shown by a rise of the phase meter, and an incidence of carbon dioxide is shown by a fall of the phase meter and a fall of the volt meter.

If both gases occur simultaneously, only the presence of carbon dioxide is shown directly, i.e. by the volt meter, whilst the phase meter will indicate the presence of methane indirectly in the sense that it shows the combined effect of both gases on sound velocity, which may, in fact, zeroise the phase meter. But a methane reading may nevertheless be taken, because a fall of the phase meter without a proportional fall of the volt meter indicates the presence of both the toxic carbon dioxide and the explosive methane, and a danger signal may be given on both counts.

Referring to Figs. 3 to 8 a constructional form of the instrument is built into a rectangular box 30 comprising a cast front plate 31 and a housing 32 joined together in an airtight manner by a seal 33 and held together by screws 34. The plate 31 is provided with an external recess 35 adjacent an internal extension 36. A variant tube 13 is formed by a semi-circular groove 37 in the recess 35 and a semi-circular strip 38. A gap 39 is left between the groove 37 and the strip 38 for the variant tube to be open to atmosphere. A bore 40 is provided in the extension 36 to accommodate a water wick for supplying constant moisture condition to the variant tube through the holes 41. Further, a bore 42 is provided in the extension 36 which is completely sealed and constitutes a datum tube 18.

The datum and variant tubes 18 and 13 are situated in close proximity in or on the same piece of metal, i.e. the extension 36, whereby the greatest possible temperature uniformity between the two tubes is ensured.

Transducers 11, 12 and 16, 17, are secured to the ends of the extension 36. The face of a phase meter 14 is visible through a glass window 43. A one-way switch 44 and a two-way switch 45 are embodied in the plate 31 so as to be situated on the inside thereof but operable from the outside; insulating means (not illustrated) being provided to prevent the entry of atmosphere into the box 30 where the switch levers penetrate the plate 31. A bulb 46 is mounted in the face of the phase meter 14 and is visible through the window 43. The

purpose of the switches and the bulb will be described hereinbelow with reference to Fig. 9.

Only some of the electrical components of the instrument are shown in Figs. 3—8 and the complete arrangement is shown in the wiring diagram (Fig. 9) it being understood that all the components are embodied within the box 30.

Referring to Fig. 9, high and low tension batteries 47 and 48 are provided, the low tension supply having the one-way switch 44. The bulb 46, which is a neon bulb, is arranged in the oscillator wiring to show whether the oscillator is working; it also has the property of stabilising the oscillator and incidentally indicates by excessive brightness a breakdown in either of the input transducers 11 or 16.

An amplifier 49 precedes the phase meter 14 which in this example comprises a ring modulator 14A followed by a DC meter 14B.

The switch 45 is interposed in one of the output leads of the transducer 12 and in the position shown in the drawings the switch completes the normal working circuit. In order to check the full scale reading of the phase meter the switch 45 is set to connect the said output lead of the transducer 12 with the input to the amplifier 49.

It will now be shown how the phase meter satisfies yet more particular conditions of practical use. These conditions are as follows: The meter readings should be able to deal with the sensitivity for which the instrument has been designed and they should be proportional to the composition change; the meter should be adaptable for a reading within a "safe" range and a "danger" range, the possibility of variations in the properties of the electronic valves of the instrument or variations in the power supply causing a faulty reading should be a minimum and especially such variations should not be able to change a "safe" indication into a "danger" indication, or *vice versa*.

As to sensitive and proportional meter readings. As described with reference to Fig. 9 the phase meter comprises a ring modulator followed by a DC meter. It is known that a ring modulator provides a DC output which can be of either sign, the output being proportional to the cosine of the phase angle between the two inputs. Thus in the region of 90° phase disconformity a zero reading is obtained at the DC meter, this being the zero of the instrument. Having regard to the shape of the cosine curve, within a range of about 60° to either side of zero the meter reading is at its most responsive, i.e. a relatively small phase disconformity produces a relatively large deflection of the meter. Further, in that range, the meter reading is an almost linear function of the phase angle, i.e. the meter reading is almost directly proportional to the composition change.

As to "safe" and "danger" readings. By shortening or lengthening one of the tubes, i.e. the transmitting distances by a fraction of a wave length the instrument zero may be made to conform to any desired proportion in the constituents of the variant gas and in particular to a predetermined danger level of impurity.

As to the effect of variations in the valves or the power supply. This is a minimum at the instrument zero, this being also the region of highest reading accuracy. The properties of the ring modulator give that variation in the amplitude of the applied signal and cannot reverse a positive into a negative reading and there can therefore be no confusion between "danger" and "safe."

To make the instrument of a readily portable size the tube lengths should be a minimum, for example, 3—4 inches. To obtain nevertheless a high sensitivity and a phase change accumulation of recordable magnitude the frequency must be supersonic, say 30 kilocycles per second.

Referring to Fig. 10, the tubes 13 and 18 are juxtaposed at their receiving ends. A transducer 80 with two opposite diaphragms 81 is adapted to transmit sound waves through both tubes. At their output ends the tubes 13 and 18 are provided with receiving transducers 12 and 17. In all other respects this arrangement conforms to the form shown in Fig. 2.

Referring to Fig. 11, sending and receiving transducers 11, 12 are each secured to a conical chamber 70. The chambers 70 are in turn secured to either end of a body 71 which contains a datum bore 18 and a variant bore 13 the latter being open to atmosphere through a slot 72. Thin diaphragms 72, 73 close the upper and lower ends of the bores 18 and 13. The output of the receiving transducer can be adjusted to zero by changing the lateral position of one of the transducers relative to the tubes or by an adjusting screw 74 which partially closes the approach to one of the bores, in this example the datum bore. If the composition of the variant gas differs from that of the datum gas, the receiving transducer will respond by a finite output.

Referring to Fig. 12, the tubes 13 and 18 are curved and sending and receiving transducers 80 and 82 of the kind employing two opposite diaphragms 81, each transducer sending in or receiving from both directions. The output side of the transducer 82 is connected via a rectifier 83 to a relay 84 for operation of a signalling device (for example a bell) (not shown in the drawings) when a predetermined magnitude of variation is reached.

It will be appreciated that where only one receiving transducer is used, phase and amplitude changes cannot be determined independently and the output of the receiving transducer is a result of any changes produced by the variant gas.

What we claim is:—

1. An instrument for determining the nature

of a gas comprising a self-excited oscillator supplying electrical energy to one or more sending transducers adapted to transmit sound energy through a vessel containing a variant gas, one or more receiving transducers adapted to receive the said sound energy, and means for comparing the electrical signals received as regards phase and amplitude with those obtained by transmission of sound energy through a datum gas in a vessel.

2. An instrument according to claim 1, comprising a self-excited oscillator, a first set of cooperating sending and receiving transducers whose sound path passes through a tube containing the gas to be determined, a second set of cooperating sending and receiving transducers whose sound path passes through a tube containing a known gas, and means for measuring the phase and amplitude of the output of the two receiving transducers relative to one another.

3. An instrument according to claim 1, comprising a self-excited oscillator, a sending transducer having two opposite sound diaphragms, one diaphragm facing the input end of a tube containing the gas to be measured, the other diaphragm facing the input end of a tube containing a known gas, a receiving transducer at the output ends of each of the said tubes, and means for measuring the phase and amplitudes of the output of the two receiving transducers relative to one another.

4. An instrument according to claim 1, comprising a self-excited oscillator, a set of cooperating sending and receiving transducers, a tube containing the gas to be determined, a tube containing a known gas, a chamber open to the sending transducer and separated by a membrane from the input ends of the two tubes, a chamber open to the receiving transducer and separated by a membrane from the output ends of the two tubes, and means for measuring the phase and amplitude of the output of the receiving transducer.

5. An instrument according to claim 1, comprising a self-excited oscillator, a sending transducer having two opposite sound diaphragms, one diaphragm facing the input end of a tube containing the gas to be determined, the other diaphragm facing the input end of a tube containing a known gas, a receiving transducer having two opposite sound diaphragms, one diaphragm facing the output end of the tube containing the gas to be determined, the other diaphragm facing the output end of the tube containing the known gas, and means for measuring the phase and amplitude of the output characteristics of the receiving transducer.

6. An instrument according to any one of claims 1 to 5 wherein the tube containing the gas to be determined is provided with an opening permitting the passage of ambient gas through the tube and wherein the tube containing a known gas is sealed against the passage therethrough of ambient gases.

7. An instrument for determining the nature of a gas constructed, adapted and arranged substantially as described herein and with reference to Fig. 1, 2, Figs. 3—9, Figs. 10, 11 or 12 of the accompanying drawings.

MEWBURN, ELLIS & CO.,
70—72, Chancery Lane, London, W.C.2,
Chartered Patent Agents.

PROVISIONAL SPECIFICATION

Improved means for Analysing Gaseous Substances

I, JOHN HUGH DAVEY WALTON, a British Subject, of Bamford House, Tetbury, in the County of Gloucestershire, do hereby declare this invention to be described in the following statement:—

This invention relates to an improved method of, and means for, analysing gaseous substances.

It is often desirable to provide means for rapidly detecting changes in the composition of a mixture of gases, i.e. detecting quantitatively an admixture or abstraction of a constituent.

An example is the use of such means in mines where it is important to detect explosive impurities, such as methane, and to signal the presence of such impurities without delay.

In the present invention use is made of the fact that changes in the composition of a gas produce changes in its sound propagation characteristics, i.e. changes in the velocity and/or the attenuation of sound passing through the gas.

It is therefore the first and principal object of the present invention to provide means for measuring the composition of a gas by a method of measuring its sound propagation characteristics, such measurement being taken in relation to a predetermined standard or datum.

Consideration will now be given to sound velocity in a gas. It is known that sound velocity in a gas is a function of the absolute temperature and of a quantity, which depends only on the nature of the gas. This quantity, which is specific to any particular gas, is hereinafter referred to as the velocity index.

In the case of a pure gas, it may be shown that $C=T^{\frac{1}{2}}(R\gamma/M)^{\frac{1}{2}}$ where C is the velocity of sound, T is the absolute temperature, R is a gas constant, γ is the ratio of the specific heats and M is the molecular weight. There-

fore the velocity index of a gas is defined as $C/T^{\frac{1}{2}}$ for which a pure gas is equal to $(R\gamma/M)^{\frac{1}{2}}$. A mixture of gases has a velocity index which is an average of the indices of its constituents.

It is therefore possible to determine the quantity of a gas being added to or abstracted from another gas, because a change in composition changes the velocity index of that composition, and it is correspondingly a more particular object of the present invention to provide means for measuring changes in the velocity index of a gas as a fraction of the velocity index before change and thereby indicate instantaneously the quantity of a known constituent which is being added or abstracted.

Generally, only one constituent at a time can be dealt with in this way; but in some cases the quantities of two constituents can be determined during addition or abstraction for the following reason. Some gases introduce considerable sound attenuation whilst in others it is negligible. In some cases it is therefore possible to measure the respective quantities of two known gases added to a known third gas, if the two gases have pronounced and negligible sound attenuation properties, respectively, and provided that separate measurement is taken of the combined effect of the two gases on sound velocity on the one hand, and the effect of one of them on sound attenuation, on the other hand.

It is therefore a still further object of the present invention to provide means for the separate measurement of sound velocity and sound attenuation in a gas.

The proposed means are applicable to cases where, for analysis or detection, it is sufficient to know that there has been a change in velocity index, either because only one or two specific constituents or impurities are likely to be present as, for example, in the air adjacent a known volatile liquid, or where the presence of any impurity calls for action as, for example, in the air inside a submarine.

The gas whose velocity index is to be measured is hereinafter referred to as the variant gas. The gas in relation to which such measurements are taken is hereinafter referred to as the datum gas. In the proposed apparatus, constructional parts concerned in dealing with the gases to be measured, are referred to as variant and datum parts respectively.

According to the present invention a method and apparatus for comparative measurement of sound propagation characteristics in a gas comprise a first set of sending and receiving transducers whose sound path is situated within a sealed vessel containing a datum gas, a second set of sending and receiving transducers whose sound path is adapted to be exposed to a variant gas, a high frequency oscillator for energising both sending transducers, and means for measuring any variation in phase and/or amplitude relationship of the output of the two receiving transducers, such variations being indicative of a relative change in sound velocity and/or sound attenuation, respectively.

The means for measuring the said variations in phase and amplitude relationship may comprise, respectively, a phase meter and a volt meter, both of known construction.

Velocity changes appear as a phase disconformity between the datum receiver and the variant receiver and is registered by the volt meter.

Both meters may be calibrated to read zero under conditions of conformity and to show any variations in terms of a percentage change in one or two constituents of the variant gas.

The oscillator is preferably provided with means for stabilization of frequency and amplitude. But it will be appreciated that a limited lack of such stabilization would not appear as a faulty reading on the meters because both the datum and the variant measurements would be affected equally.

The respective transmitting distances of the two transducer sets are of an order giving a phase change accumulation of recordable magnitude. Normally, the two transmitting distances are identical, but they may be adjusted to differ by a fraction of a wavelength to ensure zero reading at conditions of conformity.

Apparatus according to this invention may embody means for instantaneously signalling a composition change at a predetermined magnitude.

Preferably the two transducer sets are juxtaposed whereby they are both subject to the same temperature. Consequently, the effect of temperature on the sound propagation change is automatically eliminated.

Apparatus of the kind described may be made of readily portable size by employing high frequency transducers.

In cases where a variation in humidity of the gases is likely to affect sound propagation, apparatus according to the invention is provided with means for humidity stabilization. Such means preferably take the form of the installation of a drying agent or a humidifying agent adapted to ensure minimum or maximum himidity, respectively, at all times.

Further advantages of the apparatus according to this invention are that readings may be made by an unskilled person, and that all likely operation faults can be detected as such and do not show as a faulty reading. Pressure changes do not affect the readings because they do not influence sound propagation.

Two constructional forms of the present invention are illustrated in the accompanying drawing, wherein:—

Fig. 1 is a diagram of a first form of the proposed apparatus, and

Fig. 2 is a diagram of a modification.

Referring to Fig. 1 of the drawing, the apparatus comprises the following arrangement:—

A high frequency oscillator 10 of about 30 kilocycles per second is adapted to operate a datum unit 11 and a variant unit 12 by energising sending transducers 13 and 16 whose sound energy is transmitted to receiving transducers 14 and 17, through a sealed datum tube 15 and a perforated variant tube 18, respectively. The output sides of the receiving transducers 14 and 17 are wired to a phase meter 19 and a volt meter 20 as shown. The transmitting distances, i.e. the lengths of the tubes 15 and 18 are of the order of twenty wavelengths.

In this example the apparatus is adapted for installation in a mine to detect the presence of methane and/or carbon dioxide in the air. The datum tube 15 is therefore filled with a sample of clean air, whilst the interior of the variant tube 18 is exposed to the ambient air in the mine.

It is known that methane is lighter than air and it therefore transmits sound at a relatively greater velocity but it does not introduce appreciable sound attenuation. Carbon dioxide is heavier than air with a corresponding depression of sound velocity, but it does introduce sound attenuation.

Therefore an incidence of methane is shown by a rise of the phase meter, and an incidence of carbon dioxide is shown by a fall of the phase meter and a fall of the volt meter.

If both gases occur simultaneously, only the presence of carbon dioxide is shown directly, i.e. by the volt meter, whilst the phase meter will indicate the presence of methane indirectly in the sense that it shows the combined effect of both gases on sound velocity, which may, in fact, zeroise the phase meter. But a methane reading may nevertheless be taken, because a fall of the phase meter without a proportional fall of the volt meter indicates the presence of both the toxic carbon dioxide and the explosive methane, and a danger signal may be given on both counts.

Referring to Fig. 2 of the drawings, wherein like parts are given like references, a modified form of the apparatus comprises the following arrangement:—

The tubes 15 and 18 are curved, and sending and receiving transducers 21 and 22 are each provided with two opposite diaphragms, one diaphragm in respect of each of the tubes 15 and 18.

This is a simplified arrangement, but only one set of output leads is available. Hence phase changes and voltage changes cannot be obtained separately in this case.

The output side of transducer 22 is connected via a rectifier 23 to a relay 24, which is adapted to operating a signalling means (not shown in the drawing) when a predetermined magnitude of variation is reached.

In a further modification, not shown in the drawing, a double diaphragm transducer is provided only in respect of the input ends of the datum and variant tubes, and the output ends of the said tubes are spaced apart and each provided with a receiving transducer.

In order to check the zero readings, a switch may be provided to disconnect the variant unit, whereby the meters should indicate zero as if conformity existed.

A humidifying agent may comprise a wick supplied with water and provided in respect of both the datum and the variant unit.

MEWBURN, ELLIS & CO.,
70—72, Chancery Lane, London, W.C.2,
Chartered Patent Agents.

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727,891 PROVISIONAL SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

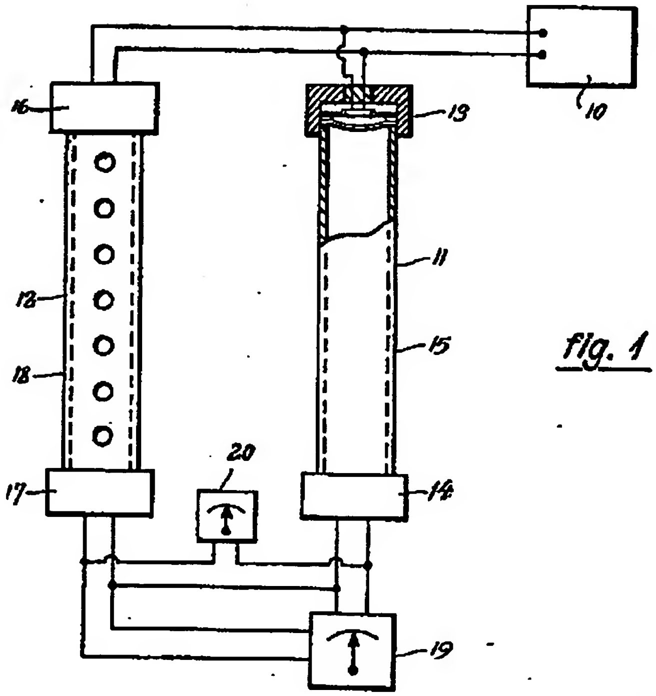


fig. 1

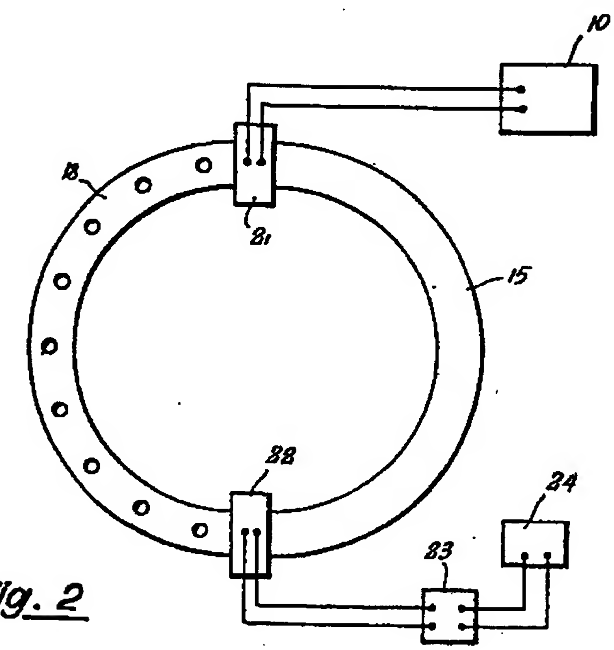


fig. 2

727,891 COMPLETE SPECIFICATION
4 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

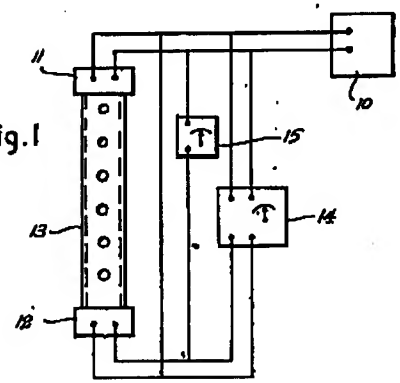


fig.1

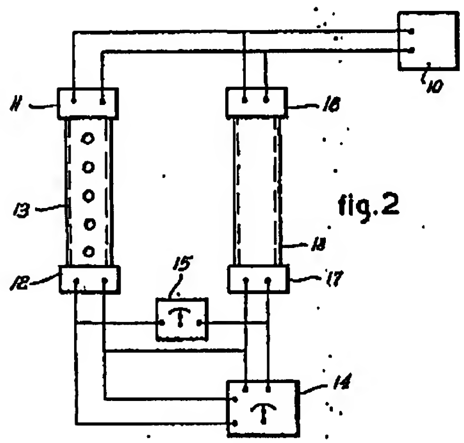


fig.2

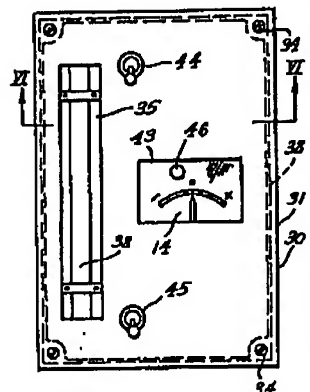


fig.3

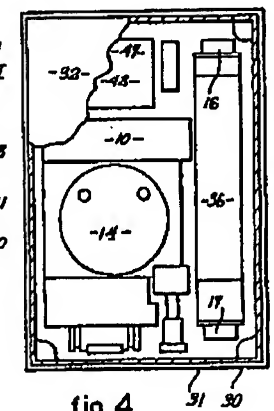


fig.4

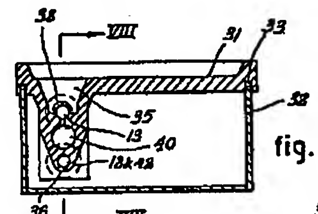


fig.6

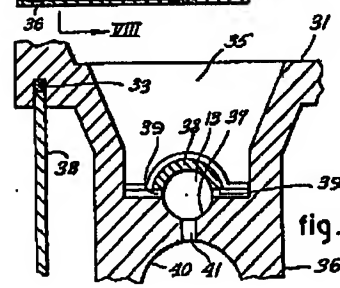
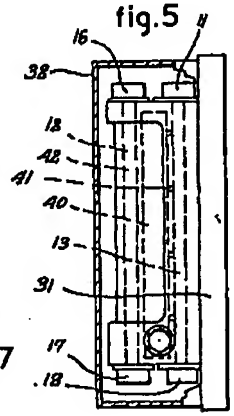


fig.7



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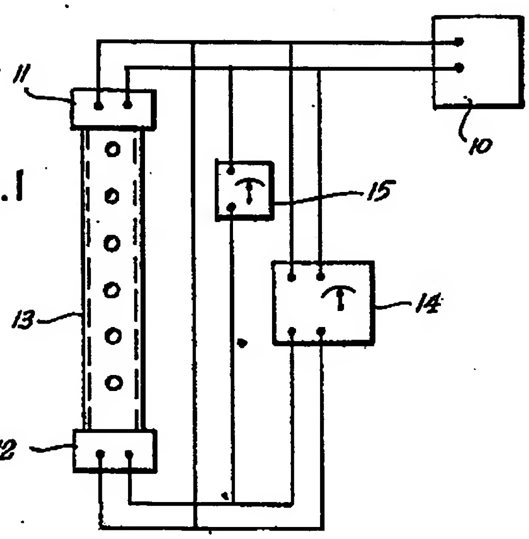
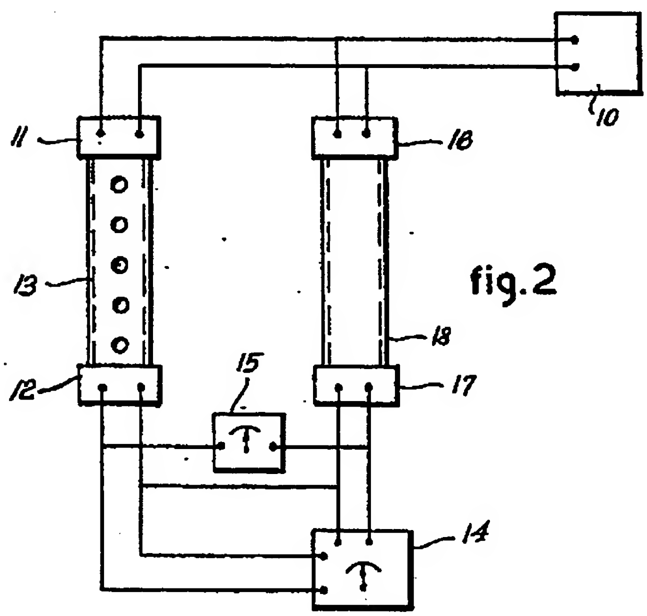


fig.1



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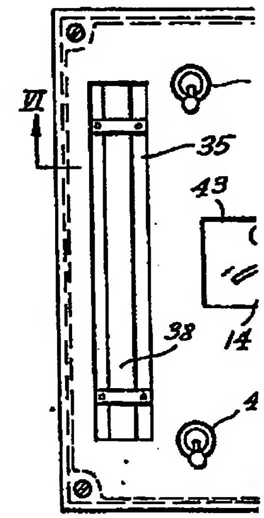

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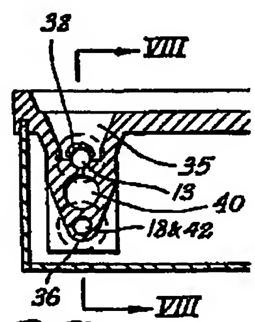

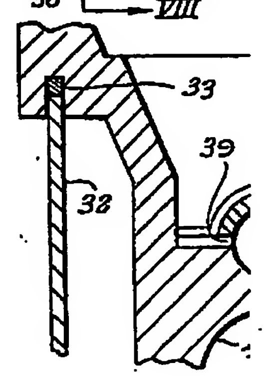

727,891 COMPLETE SPECIFICATION
4 SHEETS

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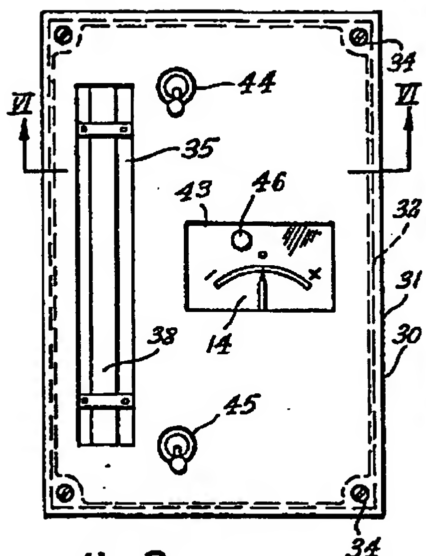
SHEETS 1 & 2



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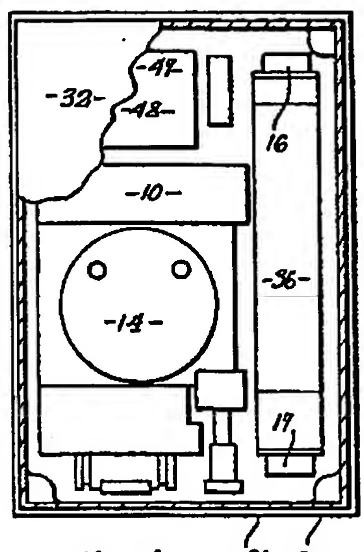

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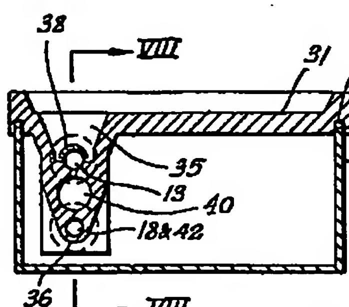
fig.4



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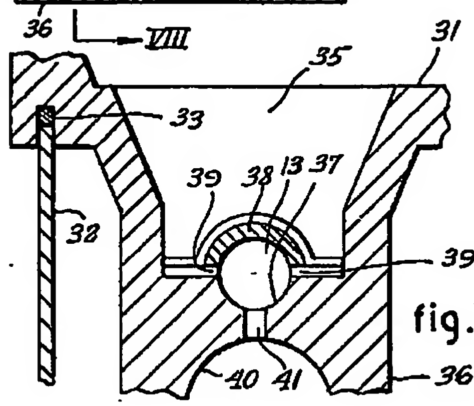
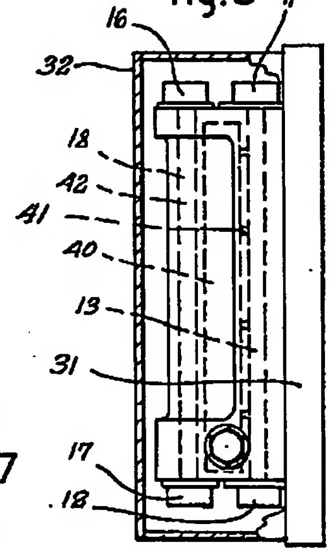


fig.7

fig.5



727,891 COMPLETE SPECIFICATION
4 SHEETS
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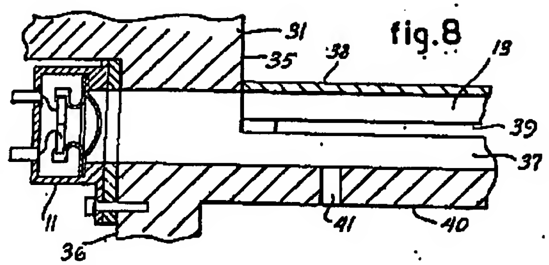
SHEETS 3 & 4

fig.8



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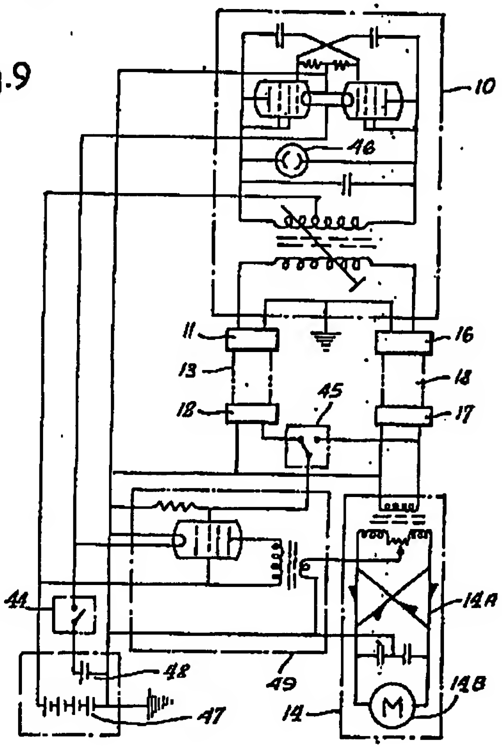
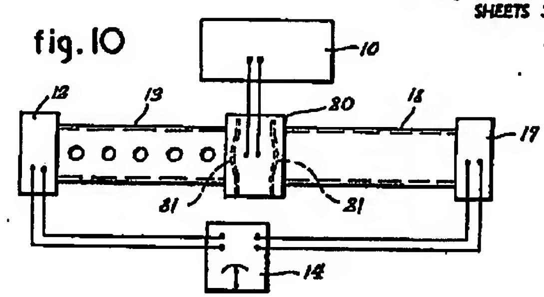


fig.10



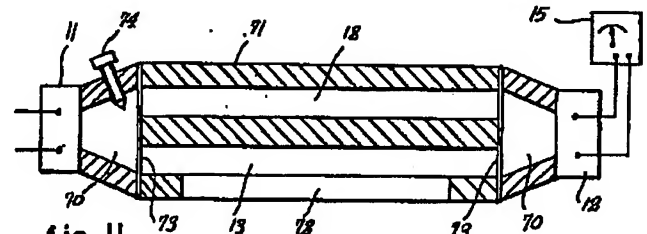
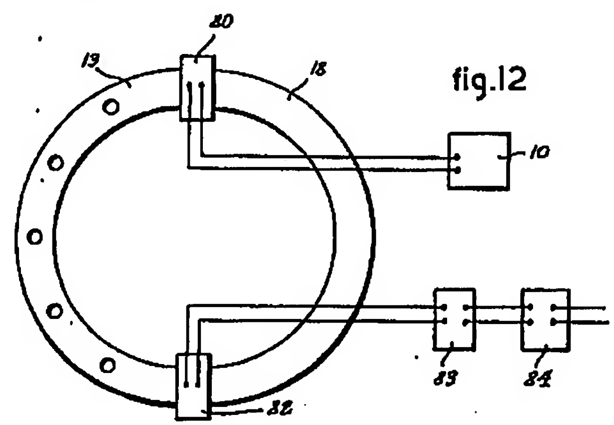


fig.11

fig.12



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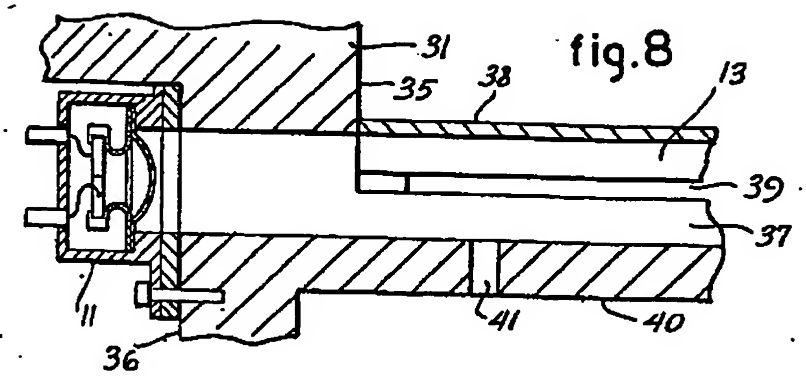

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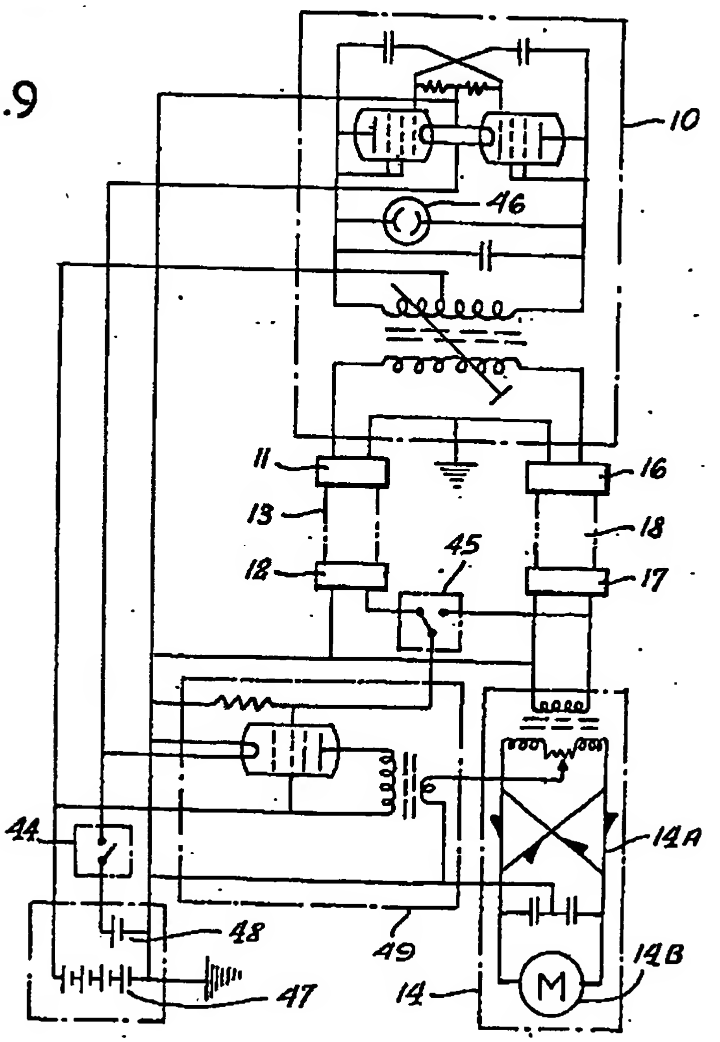
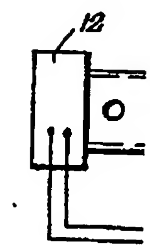
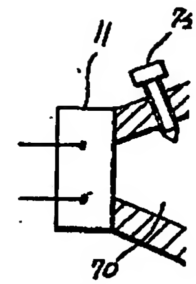


fig.1





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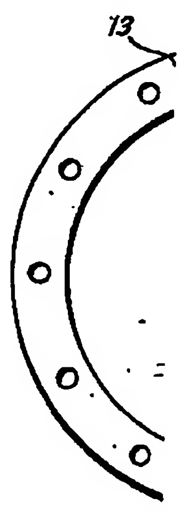

727,891 COMPLETE SPECIFICATION
4 SHEETS
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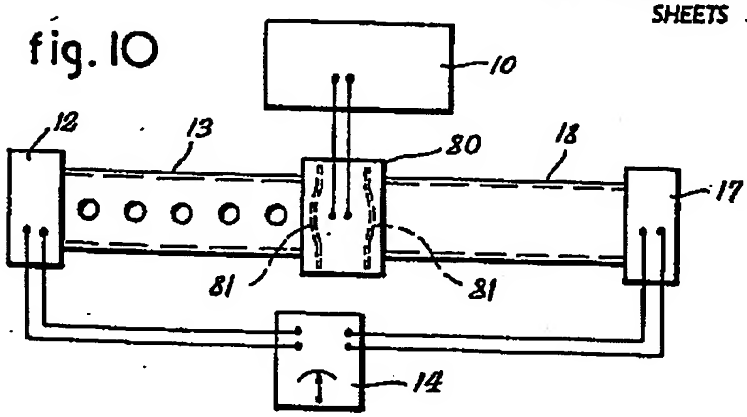
SHEETS 3 & 4

fig. 10



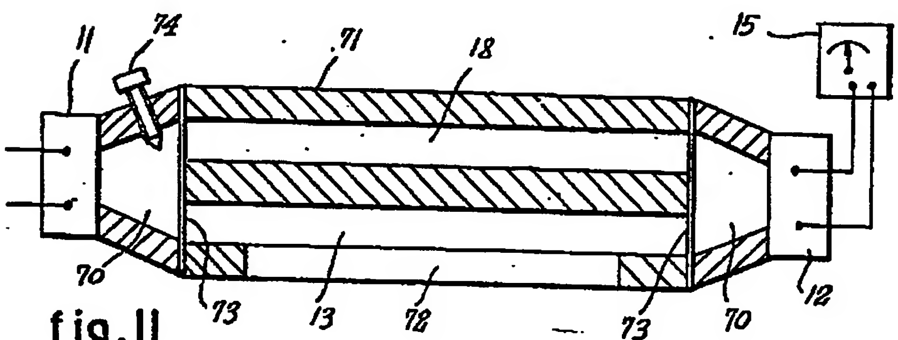


fig. 11

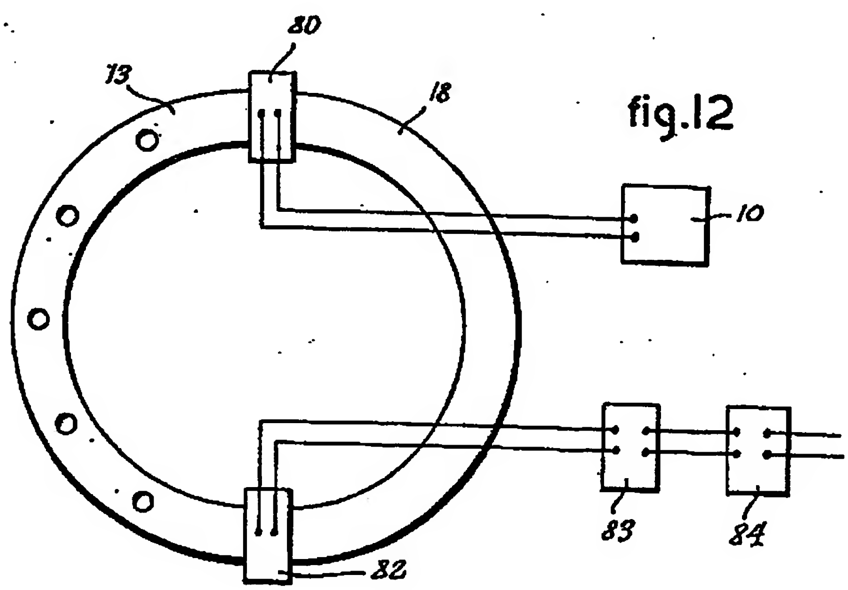


fig. 12

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